Chris Wilkson's Oscilloscope Probe Notes

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1 Introduction

A oscilloscope probe is a cable containing a passive or active circuit to modify the input impedance of an oscilloscope. An oscilloscope impedance consists of resistance and capacitance.

2 Properties of a 10x Probe

The impedance of a capacitor of capacitance C, is given by

$$\frac{1}{j\omega C} = -\frac{j}{\omega C},$$

where j is the imaginary unit, and where ω is the angular frequency in radians per second, and which is

$$\omega = 2\pi f,$$

where f is the frequency in cycles per second.

Suppose an oscilloscope has a load impedance of a resistor R_1 and a capacitor C_1 connected in parallel from the input terminal to ground. Then the impedance is defined by

$$\frac{1}{Z_1} = \frac{1}{R_1} + \frac{1}{1/(j\omega C_1)} = \frac{1}{R_1}(1 + R_1 C_1 \omega j)$$

or

$$Z_1 = \frac{R_1}{R_1 C_1 \omega j + 1}.$$

The probe consists of a resistor R_2 in parallel with a capacitor C_2 and has impedance

$$Z_2 = \frac{R_2}{R_2 C_2 \omega j + 1}.$$

So the impedance seen from the tip of the probe is

$$Z = Z_1 + Z_2.$$

Let us take $R_2 = 9R_1$ and $C_2 = C_1/9$

Then

$$Z = Z_1 + Z_2 = \frac{R_1}{R_1 C_1 \omega j + 1} + \frac{9R_1}{9R_1(C_1/9)\omega j + 1}$$
$$= \frac{10R_1}{R_1 C_1 \omega j + 1}.$$

This can be rewritten as

$$Z = \frac{10R_1}{10R_1(C_1/10)\omega j + 1},$$

which is equal to the impedance of a resistor $10R_1$ in parallel with a capacitor $C_1/10$. So the equivalent load seen at the probe tip has the resistance multiplied by 10 and the capacitance divided by 10.

Let voltage V_2 be the voltage seen at the oscilloscope input, and V_1 the voltage at the probe, then

$$V_2 = V_1 \frac{Z_1}{Z_1 + Z_2}.$$

$$Z_1 + Z_2 = \frac{R_1}{R_1 C_1 \omega j + 1} + \frac{9R_1}{9R_1(C_1/9)\omega j + 1} = 10Z_1,$$

Therefore

$$V_2 = V_1 \frac{Z_1}{10Z_1} = \frac{V_1}{10}.$$

So 1 volt at the oscilloscope corresponds to 10 volts at the probe, that is 10X.